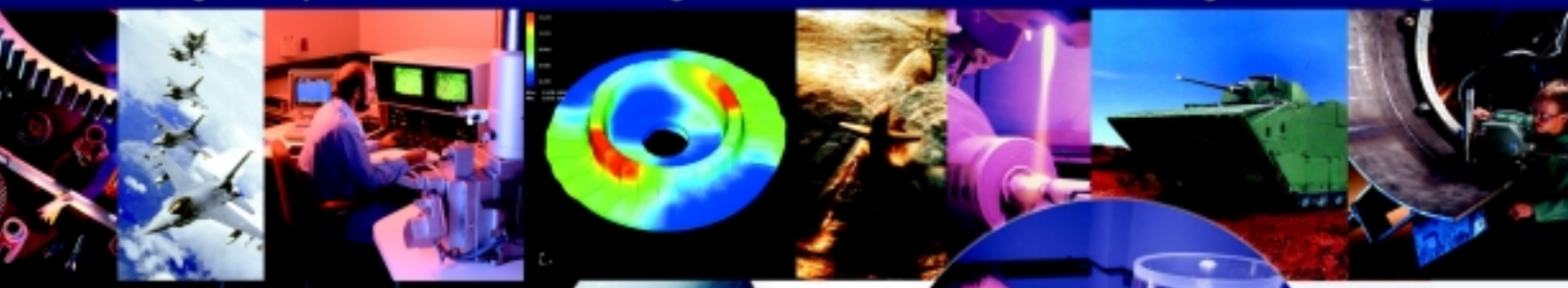
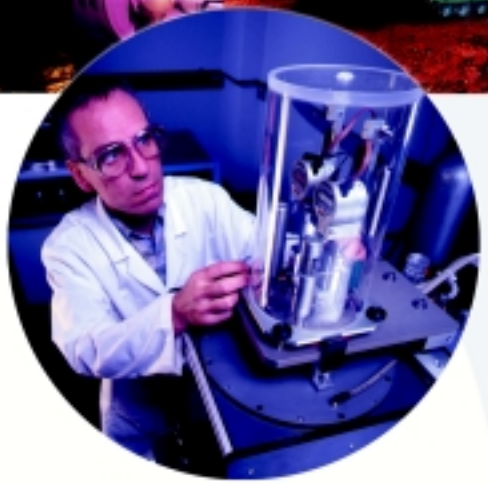
Ensuring Navy Readiness Through Affordable Metalworking Technologies





NCEMT

National Center for Excellence
in Metalworking Technology

2001 Annual Report

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For 13 years, the NCEMT has been tireless in its drive to support military needs by developing and disseminating world-class metalworking solutions that continually revolutionize combat capabilities. Now, as the United States deals with new defense and security issues, the NCEMT is rededicating itself to service, support and innovation. The NCEMT, always expeditious in delivering results, is stepping up the pace of discovery and deployment to ensure that the needs of U.S. warfighters are met.

Working together, the U.S. Navy Manufacturing Technology (MANTECH) Program, and the National Center for Excellence in Metalworking Technology (NCEMT) are making the best metalworking technologies even better in support of U.S. Naval readiness.

I am proud of the outstanding work we have undertaken. The NCEMT, in the first year of its new five-year, competitively awarded contract, is extending the accomplishments of its mission: advancing research, achieving results and serving our country well.

Since its founding 13 years ago, the NCEMT has surpassed expectations, redefining standards of excellence in metalworking technology. The NCEMT's ability to deliver and disseminate affordable, innovative manufacturing solutions is helping to ensure that the world's most sophisticated defense program will continue also to be the world's most capable.

Sincerely,

Steven M. Linder

Steven M. Linder
Director
Manufacturing Technology
(MANTECH) Program
Office of Naval Research

As Admiral Vem Clark, U.S. Navy Chief of Naval Operations, noted, "New circumstances demand that we think and act in new ways at every level of the Navy—from work center to Navy headquarters. Time and tide wait for no one….We sail anytime, anywhere as powerful representatives of American sovereignty."

These words remind us that our responsibility to America's warfighters is motivated by a sense of mission. Like theirs, our resolve is firm, our commitment is unwavering.

In partnership with government and industry, the NCEMT is working to produce and maintain combat vehicles that are lighter, stronger and faster. This publication reports on several innovative projects that are underway at the NCEMT. And it showcases achievements made possible through the experience gained over our 13-year history. A history marked by service excellence.

From the moment new projects hit the drawing board, they start with a big advantage: the benefit of the NCEMT's sound and solid expertise. American government and industry have long expressed confidence in the NCEMT's ability to produce outstanding results, undertake bold new assignments and meet critical challenges. And the NCEMT remains committed to advancing U.S. defense.

We at the NCEMT are pleased to have a role in supporting America's heroes, the men and women of the Armed Forces. Please feel welcome to contact me with your questions or comments. I look forward to providing you with information about the NCEMT and the advanced metalworking solutions we can offer.

Sincerely,

Richard J. Henry

Richard J. Henry
Program Director
National Center for Excellence in Metalworking Technology

State of the NCEMT

The state of the NCEMT? Ready. Capable. Agile. Escalating the drive to discover more, reach higher and top past achievements.

The NCEMT, established by the Navy Manufacturing Technology (MANTECH) Program in 1988, is working on a variety of projects to ensure the availability of proven, affordable technology capable of meeting military-unique demands.

Scientists, engineers and other experts at the NCEMT are partnering with industry and government leaders to identify key areas that need to be addressed to meet defense goals. Out-of-the-box thinking is encouraged. New paradigms are essential.

As one key partner, the Naval Sea Systems Command (NAVSEA), puts it: "We're working smarter so Sailors don't have to work harder."

The NCEMT team is energized by the new challenges and accomplishments made possible as a result of our new five-year, competitively awarded contract.

In 2001, the NCEMT achieved a number of technological firsts. For instance, NCEMT engineers successfully used plasma hearth melting to cast titanium slabs in rectangular shapes, which will help enable the alloy to be used in armor plates. NCEMT engineers successfully fabricate Aluminum 2519 Friction Stir Welding (FSW) butt welds that passed the ballistic shock test at an impact velocity above the specification. As a result, the strength and ductility of welds used on the Advanced Amphibious Assault Vehicle (AAAV) can be greatly improved.

Another highly anticipated first at the NCEMT is the application of the new FSW unit to solve Army and Navy fabrication problems. Using the new unit, the NCEMT will soon be able to weld full-size combat vehicles.

By leveraging proven technologies, the NCEMT and its partners are able to expedite projects, do the job right the first time and deliver technology that helps keep U.S. warfighters combat-ready at a moment's notice.

We are proud of our work on such prestigious projects as the DD 21—Zumwalt-Class 21st Century Destroyer. It is good to know that U.S. missiles can now have extended range, improved thrust, faster rates of climb and greater payloads because the NCEMT discovered a better way to form nickel-based, single-crystal alloys. It is reassuring to remember that because the NCEMT optimized the manufacture of powder metal isothermally forged Udimet 720, the capabilities of turbine-powered aircraft are significantly improved. Project after project, start to finish to technology transfer, the NCEMT continues to deliver world-class solutions to metalworking technology.

The world is depending on American technology, ingenuity and spirit. As guardians of the most successful democracy mankind has known, we stand united in the task before us. ✪

To develop and deploy superior quality weapons systems. . .

for the U.S. Navy, the NCEMT recruits the best and brightest professionals and gives them the tools they need to succeed.

Forming Smart Partnerships

The people behind the projects at the NCEMT are skilled scientists and engineers who take pride in pushing the envelope of technological and scientific advancement. In addition, the NCEMT partners with the U.S. Navy, the Department of Defense, industry and academia to assemble Integrated Project Teams (IPTs) of highly trained experts from a broad range of backgrounds. Carefully selected professionals who join IPTs help the NCEMT leverage the domestic knowledge base.

The NCEMT's experience with IPTs is a case study in success. Benefits include being able to identify potential problems early in the development process and to engage key stakeholders before false starts happen. Risk is reduced, costs are contained and implementation is ensured.

For example, the new "Low-Cost Fabrication Processes for Advanced Amphibious Assault Vehicle (AAAV) Components" MANTECH project includes an IPT consisting of the NCEMT, the AAAV Program office, General Dynamics Land Systems and their subcontractors/suppliers.

This team is charged with identifying viable new manufacturing processes that will reduce acquisition costs and increase producability of numerous components of the Marine Corps AAAV.

Another example, The Thin-Wall Casting Project, illustrates cost sharing at its best. The IPT includes Rolls-Royce Corporation, which matched the MANTECH commitment dollar for dollar. Rolls-Royce, an industry leader, believes the Thin-Wall Casting Project has tremendous commercial potential and is willing to invest in and expedite the development process.

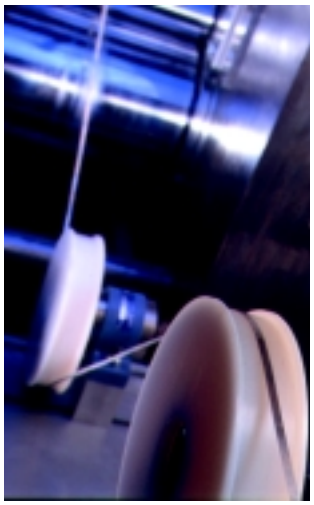
Offering High-Tech Capabilities

The NCEMT has been delivering reliable, affordable metalworking solutions to the civil-military industrial base for 13 years. A respected leader in its field, the NCEMT has developed state-of-the-art capabilities in advanced materials testing, process development, technology transition and deployment and training and education for advanced metalworking technologies. All project activities are conducted in compliance with the ISO 9001 quality program and the ISO 14001 environmental program in effect at the NCEMT.

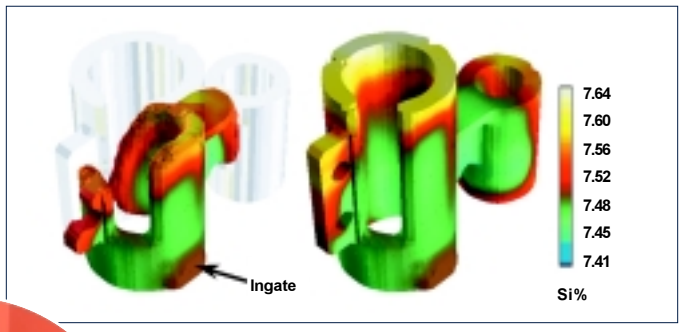
Creative solutions to highly technical problems require new ideas, critical thinking and, often, entirely new ways of doing things.

The methods by which the NCEMT addresses projects are as cutting-edge as its inventions. For example, the NCEMT has taken concurrent engineering to a new level. Rational Product & Process Design® (R·P²D®) ensures that product design and process design occur simultaneously, enabling the development of cost-effective products that perform at optimum capacity.

R·P²D incorporates environmental considerations in product and process design to minimize adverse environmental impact throughout the product life cycle. In addition, it reduces or eliminates the need for trial-and-error methods of prototyping. R·P²D is a quick and efficient way to develop product and process specifications for virtually any type of material or manufacturing process. This is particularly important when there is a need to insert new technology rapidly in response to unforeseen threats.



The tools and demonstration facilities available at NCEMT sites are unquestionably world class. Clients appreciate the opportunity to observe and access metal forming, extrusion, forging, rolling, semi-solid metalworking (SSM), powder compaction, powder injection molding and welding processes at the NCEMT. These

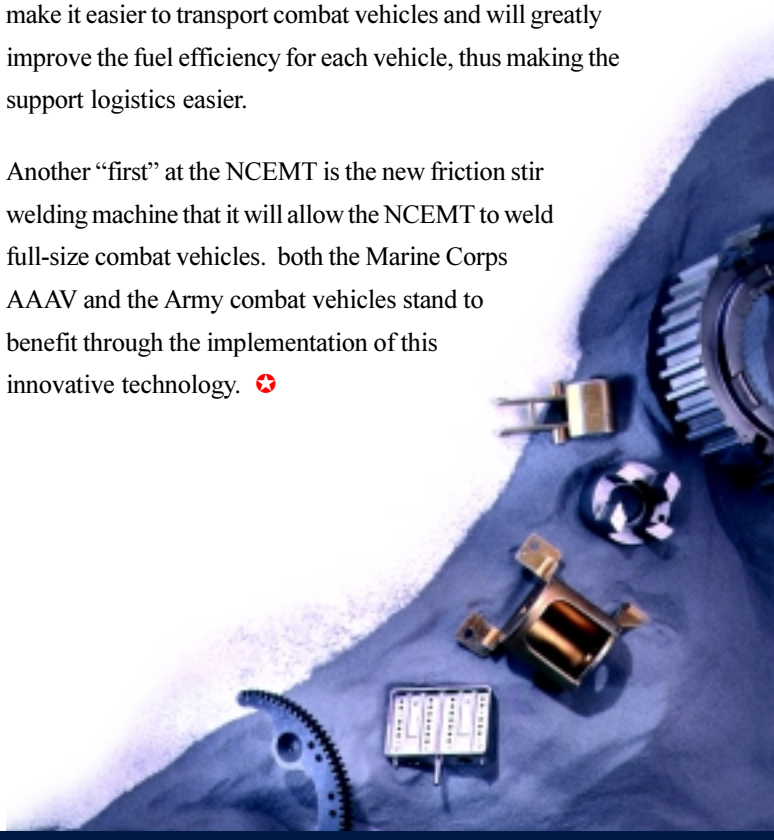


demonstration facilities provide a cost-effective means of testing, evaluating and refining metalworking processes prior to implementing these processes in production.

In addition to improving performance and lowering cost, reducing risk is critical. The NCEMT delivers proven, thoroughly tested technologies to its industrial and defense clients. This saves clients time and money, while assuring a high level of confidence in the final product.

Over the past year, the NCEMT has developed many exciting new capabilities. For example, our engineers became the first to successfully cast a titanium slab using plasma hearth melting. Ultimately, as NCEMT engineers refine and perfect the process, U.S. combat vehicles will be able to utilize low-cost, light-weight, high-performance titanium. This important development will make it easier to transport combat vehicles and will greatly improve the fuel efficiency for each vehicle, thus making the support logistics easier.

Another "first" at the NCEMT is the new friction stir welding machine that it will allow the NCEMT to weld full-size combat vehicles. both the Marine Corps AAAV and the Army combat vehicles stand to benefit through the implementation of this innovative technology. ✪



Lighter. Stronger. Faster. . .

The U.S. Navy is mandating that its fleet meet aggressive new standards: Vessels must weigh and cost less, yet have increased survivability and performance. The NCEMT and its government and industry partners are responding to the call by developing technology that will help make ships and submarines which exceed the capabilities of all vessels that have come before.

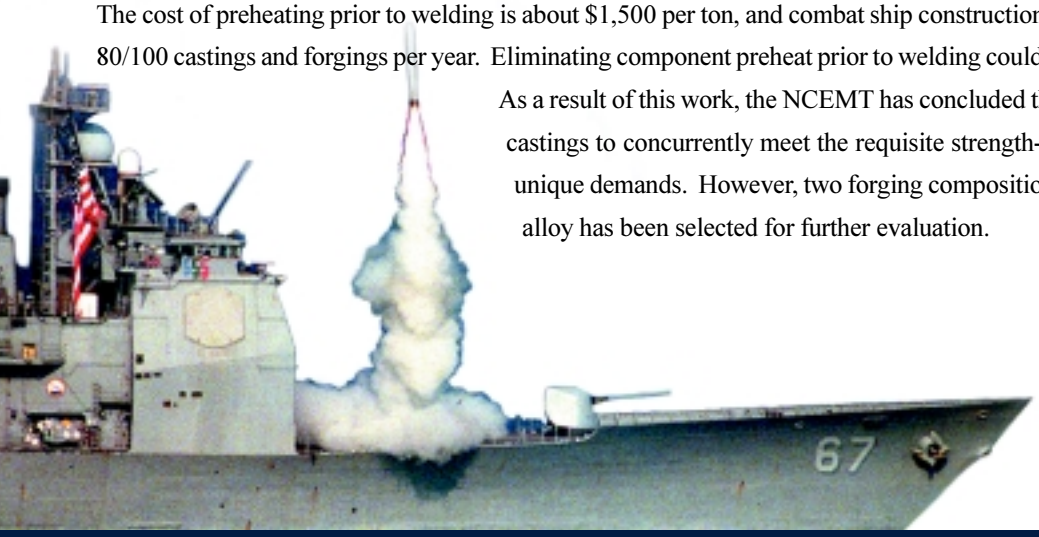
U.S. Navy aircraft carriers (CVNs) and submarines (SSNs) utilize approximately 250 tons each of high-yield strength HY-80 ksi and HY-100 ksi steel castings and forgings. The NCEMT is improving the process for high-strength steel castings and forgings, reducing costs and weight and enhancing weldability and resistance to hydrogen-assisted cracking (HAC).

This initiative began in response to studies by Naval Sea Systems Command (NAVSEA), which identified several problems with HY-80 and HY-100 steels—HAC in castings, excessive hardness and low toughness resulting from improper heat treatment and high costs due to preheat requirements. NAVSEA challenged the NCEMT to solve these problems and reduce fabrication costs by eliminating the preheat of HY-80/100 components during welding.

As a result of this effort, the NCEMT has already transferred valuable technology to the Navy, shipyards and foundries, demonstrating how to determine the optimum thermal soaking treatments to mitigate hydrogen embrittlement and HAC in high-strength steel castings. These tools will make it possible for foundries to identify potential HAC locations and will lead to process improvements for reduced or redistributed residual stresses and/or hydrogen levels in castings.

The cost of preheating prior to welding is about $1,500 per ton, and combat ship construction and refitting require about 1,100 tons of HY 80/100 castings and forgings per year. Eliminating component preheat prior to welding could result in $1.65 million in cost savings annually.

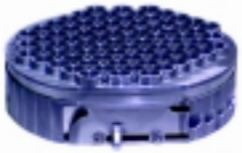
As a result of this work, the NCEMT has concluded that major chemistry alterations are required for castings to concurrently meet the requisite strength-and-toughness levels necessary for military-unique demands. However, two forging compositions have shown promise, and an HSLA-100 alloy has been selected for further evaluation.



Lightweight Radial Manifolds

The NCEMT successfully reduced the cost and weight for the High-Temperature Lightweight Radial Manifold (HTLRM) used in the Concept 1 Dispenser Subsystem—an assembly that forms part of the Surface Ship Torpedo Defense Soft Kill Countermeasure (SSTD) suite that is under development by the US/UK SSTD Joint Program Office.

After evaluating four material/process combinations, the NCEMT found that machined 6061-T6 could be optimized for each manifold plate and manifold assembly, achieving weight-and-cost reductions. The aluminum manifold weight was reduced from 2.85 kg to 1.80 kg. At the obtained machining cost of $2,552 per system, the present-value cost avoidance is $42.2 million based on MANTECH guidelines.



Thermal Plate Forming for DD 21

The Navy Joining Center (NJC) and the Institute for Manufacturing and Sustainment Technologies (iMAST), MANTECH Centers of Excellence, have shown that thermal sources may be used to deform large plates without hard tooling. The NCEMT has been tasked to further this research and provide recommendations for the most beneficial forming system for future combat surface ship hulls.

The outer hull of new Naval combatants is constructed of moderately thick steel plating. Regions of this plating require complex, three-dimensional curvature for hydrodynamic and signature considerations. Since hull plating is only a small part of the total construction cost for a warship, plate-forming processes have not been optimized and currently require large amounts of skilled labor. It is the NCEMT's goal to fully evaluate the need-and-cost basis for plate forming within the DD 21 Alliance Shipyards and to develop a viable combination of technologies to meet that need.

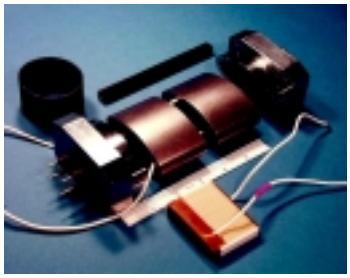
Controlling Flash-Rust at Shipyards

Reducing the occurrence and severity of flash-rust on ships and submarines will save time and reduce blasting-and-painting costs. Flash-rust is a thin layer of tightly adherent oxide film that requires substantial effort to prevent, minimize and repair. Being able to measure flash-rust and to understand how it affects coating performance will help shipyards apply their coatings in a more cost-effective manner and decrease the likelihood of a coating failure.

Experiments underway at the NCEMT are expected to produce a recommendation for a uniform, Navy-approved flash-rust standard and qualitative measurement technique. This is expected to result in an estimated 80 percent reduction in rework associated with flash-rust to restore surfaces to specified conditions, which translates into significant annual savings for every shipyard building Navy vessels.

Improving Sonar Systems

The goal of this project is to improve the mechanical reliability of high-power lead magnesium niobate (PMN) ceramics for Navy transducer applications. Attaining this goal will yield more reliable transducers that are lighter and smaller and have a higher output than current transducers containing lead zirconium titanate (PZT). The NCEMT performed mechanical testing-and-failure analysis on PMN and transferred this information to the Lightweight Broadband Variable Depth Sonar (LBVDS) Program and their suppliers.

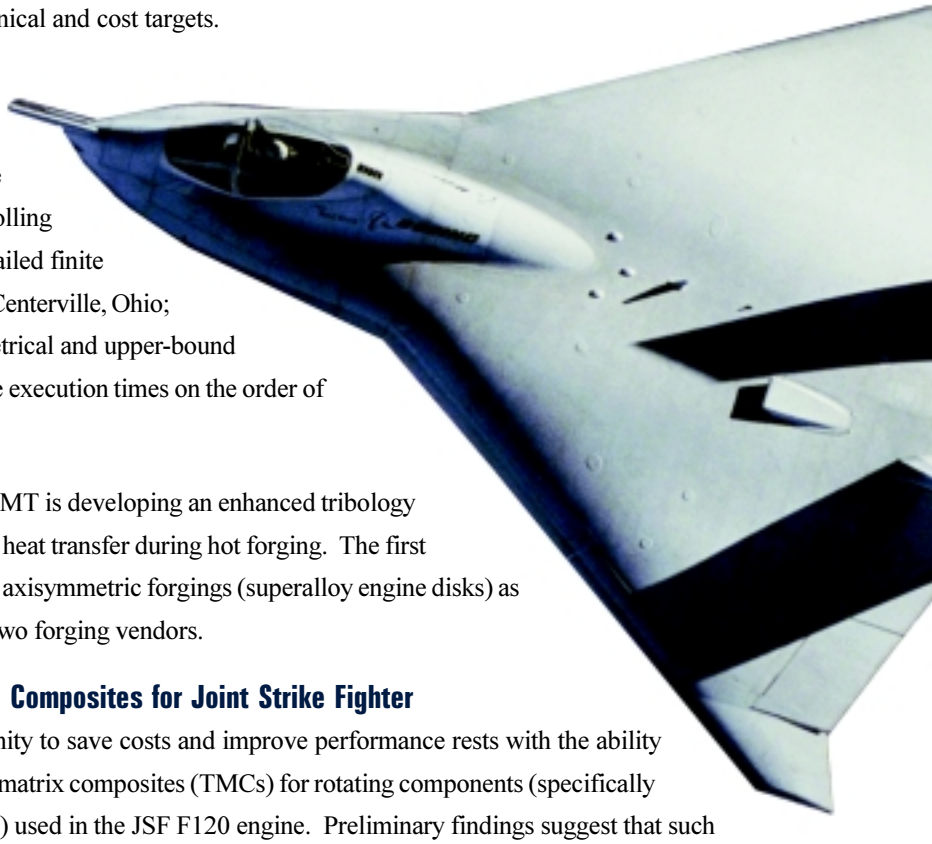


PMN is the critical enabling technology for advanced active sonar concepts. Through the LBVDS Program, a joint effort of the NAVSEA Newport Division and Lockheed Martin Corporation, the Navy will implement an improved towed active sonar array capable of significant acoustic power at depths below the surface layer. It will be of major importance in littoral waters against slow-moving or stationary targets in high-clutter environments. ✪

Achieving readiness objectives. . .

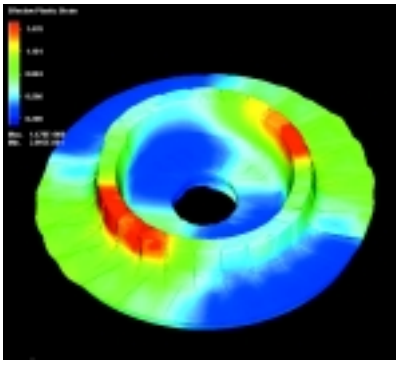
Meeting performance goals. Finding a better way. That is how the NCEMT has earned a reputation for excellence in metalworking technology and as a capable partner in a variety of key defense projects including the Joint Strike Fighter (JSF), the V-22 Osprey, and other aircraft.

To reach the affordability goals of the JSF and other military aircraft, the Air Force/Navy Forging Supplier Initiative aims to lower by 35–40 percent the acquisition costs of aerospace forgings such as airfoils, cases, integrally bladed rotors, rings and shafts. A Pratt & Whitney Engines-led team has been awarded an Air Force contract to achieve these cost reductions on specific forged parts in the JSF-F119 engine. As part of this effort, the NCEMT has management responsibility for a Navy MANTECH project that supports the technical activities of three forging vendors and helps them to achieve their technical and cost targets.



Current ring-rolled components have an unusually high buy-to-fly ratio, and the raw materials are expensive. Until recently, there were no design and simulation tools suitable for use by ring-rolling suppliers. To rapidly evaluate ring-rolling preforms, develop die shapes and generate inputs for a detailed finite element analysis, the NCEMT; Applied Optimization, Inc., Centerville, Ohio; and Ohio University, Athens, Ohio, have developed geometrical and upper-bound elemental techniques (UBET). These simulation tools have execution times on the order of minutes and have been released for use by vendors.

In association with the University of Notre Dame, the NCEMT is developing an enhanced tribology module for modeling the evolution of interface friction and heat transfer during hot forging. The first version of this model has been implemented for isothermal, axisymmetric forgings (superalloy engine disks) as a DEFORM-2D user-subroutine and has been released to two forging vendors.



Titanium Matrix Composites for Joint Strike Fighter

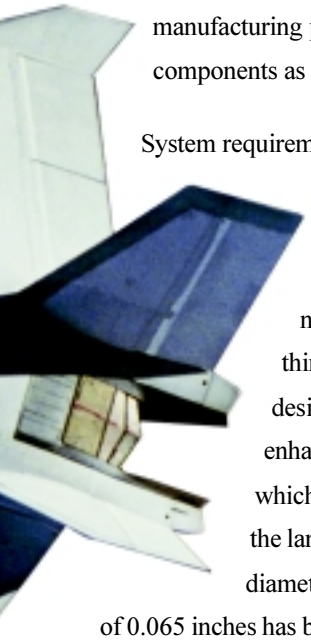
Another opportunity to save costs and improve performance rests with the ability to adapt titanium matrix composites (TMCs) for rotating components (specifically disks and spacers) used in the JSF F120 engine. Preliminary findings suggest that such an adaptation can lead to significantly improved life-cycle costs because rotating components made with TMCs can be expected to last 20 percent longer than the components currently in use.

Rotating components primarily used for the JSF F120 engine as disks and spacers are made from titanium Ti-6Al-4V. A team including the NCEMT, Rolls-Royce Corporation and Atlantic Research Corporation is working to replace titanium with TMCs, which are lighter and stronger.

Thin-Wall Casting Enhancements

Rolls-Royce Corporation is also working with the NCEMT on a project designed to manufacture less-expensive, more-capable, thin-wall diffuser/combustor cases for the AE1107C engine used on the V-22 Osprey helicopter. When the new technology is completed and implemented, a $6,000 cost reduction per diffuser/combustor case is expected.

Currently, the components are manufactured as fabricated and machined titanium parts by Rolls-Royce. An alternative manufacturing process has been identified to cast these components as single-piece parts using a nickel-based alloy.



System requirements dictate that the component weight be no more than the current titanium design, which presents a challenge. Because of the difference in material density, the nickel-based design must rely upon much thinner sections than the titanium-based design. Therefore, the casting process must be enhanced to accommodate the component, which has two concentric thin-wall regions with the largest being approximately 20 inches in diameter and 11 inches in length. A wall thickness of 0.065 inches has been demonstrated on a full-scale stylized design. Expectations are that further development of the process will allow a wall thickness of 0.050–0.055 inches in the final component design.

The casting process is capable of producing thin-walled castings without porosity or other defects common to expansive thin-wall regions. This is important because pressure tightness is necessary in the part. Furthermore, casting process parameters can be carefully controlled to assume that the resulting

microstructure is very uniform and equiaxed. This ensures a good quality casting with the required mechanical properties.

Rolls-Royce Corporation, a key IPT member, has provided significant cost share in support of this MANTECH effort. The new casting technology has potential applications within other Department of Defense and civilian aircraft engines. Technology transfer, as always, is key to the mission of the NCEMT and all MANTECH Centers of Excellence. ✪

Superior weapons systems with unmatched. . .

precision, strength and performance are ensuring U.S. dominance in modern Naval warfare.

The NCEMT, along with its civil-military partners, has long been diligent in the pursuit of advanced metalworking technologies to make the best missiles and ordnance even better. And the work continues.

One way to further improve fleet readiness without budget augmentation is to reduce manufacturing costs and increase production rates for advanced thermal batteries. The military uses these batteries to power guided artillery, missiles, sonobuoys, guidance systems and countermeasure devices. The NCEMT has identified key cost drivers of the thermal batteries used in the AN/SSQ-62E sonobuoy and the Joint Direct Attack Munitions (JDAM) guidance kit and estimates that manufacturing costs can be decreased by 17 percent.

The technology developed to improve the thermal battery manufacturing process will be applied to the Assault and Special Missions Program (PMA-264) and is of direct interest to the Air-to-Air Missile Systems Program (PMA-259). In addition, the technology can benefit many other Department of Defense (DoD) weapons systems.

AAAV Advancements

The Advanced Amphibious Assault Vehicle (AAAV), one of the major weapon platforms under development by the U.S. Marine Corps, is an armored personnel carrier with a maximum allowable vehicle weight of 76,000 pounds. The AAAV can be launched from a ship and can travel in littoral waters at speeds of up to 25 knots. Upon reaching shore, it will switch to ground-transport mode.

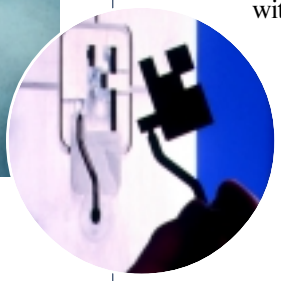
The NCEMT is working with General Dynamics Land Systems (GDLS) and the AAAV Program Office on a variety of projects associated with the assault vehicle. Under evaluation: extrusion, friction stir welding (FSW), corrosion resistance and component manufacturability.

The overall goal of the AAAV project is to achieve the highest possible degree of survivability, mobility, lethality and reliability—all at a minimal weight.

To meet these requirements, it is necessary to optimize aluminum alloy 2519, the main structural alloy for the vehicle's hull.

The NCEMT has developed FSW parameters that produce welds for 2519 with significantly higher strength and ductility than conventional gas metal arc (GMA) welds. It is advantageous to find ways to adopt FSW, which offers superior strength and ductility, elimination of filler

wire, superior corrosion resistance, greatly simplified weld preparation procedures and enhanced environmental safety as compared to GMA welds. NCEMT engineers have successfully fabricated 2519 FSW butt welds that passed the ballistic shock test.



The NCEMT has also had success in developing the manufacturing technology required to produce quality 2519 extrusions, another industry first.

The 2519 extrusions demonstrated a 28 percent increase in yield strength and a 47 percent increase in tensile strength compared to similar aluminum alloy 6061 extrusions.

Corrosion resistance is also under study because 2519 is more susceptible to corrosion than lower-strength aluminum alloys. In addition, the NCEMT is evaluating the stress-corrosion cracking (SCC) susceptibility of 2519 in the product forms and tempers that may be used on the AAAV.

AAAV-shaped components are also under study. Under the project, the NCEMT "Low Cost Fabrication Processes for AAAV Components" is assessing a variety of alternative manufacturing processes suitable for producing various AAAV components that weigh less and cost less, yet offer superior performance.

In another project, "Single-Melt Process for Reduced-Cost Titanium Alloys," the NCEMT will establish a cost-effective, single-step hearth-melt process that will reduce the production cost of strong, lightweight titanium alloy ingots. This process will emphasize plasma arc cold hearth melting (PAM). Once perfected, the single-melt process will become the industry standard for low-cost titanium alloys, giving the U.S. a technological advantage over competing nations.

Rhenium Fabrication Processing

Both NASA and the Department of Defense rely on rhenium because, among other attributes, it has an extremely high melting temperature and is immune to thermal shock. However, rhenium is hard to machine and shape. The NCEMT's challenge is to develop cost-effective fabrication methods for rhenium.

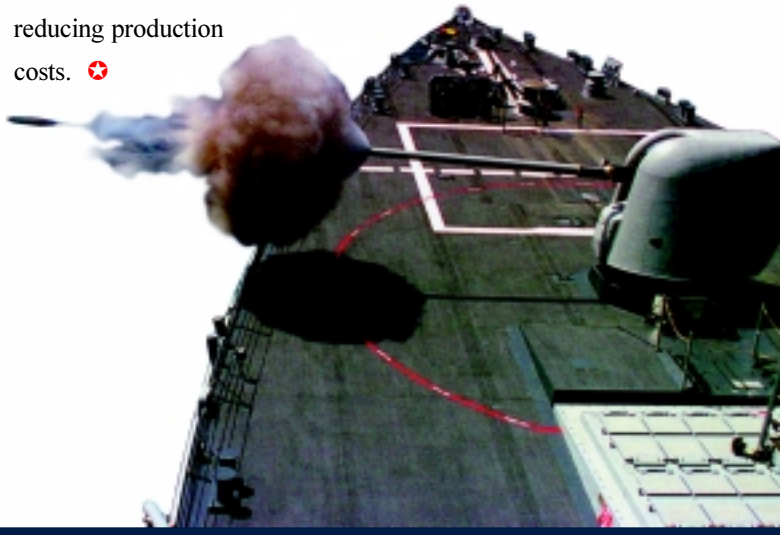
Specifically, powder metallurgical processing to near-net shape, machining and deformation processing tasks are underway. The NCEMT has successfully molded, debound and sintered rhenium tensile bars using powder injection molding (PIM). And, along with industry partner Steinmetz, Inc., the NCEMT is developing ways to use disposable plastic molds that have been made by rapid prototyping methods for PIM. As a result, complex parts—which were difficult to make otherwise—can be made faster and more economically.

In addition, rhenium can be machined by electric discharge machining (EDM), although the process may cause damage to the workpiece. The NCEMT has analyzed the EDM process and established virtually damage/contamination-free methods for EDM of rhenium. Beta-site testing is underway.

Optimized Flowformed Cartridge Cases

Navy 5-inch guns use a steel cartridge case to contain the primer and the propellant for the round. These cases had been manufactured using the deep-drawing process, which is no longer cost effective. The Naval Services Warfare Command-Indian Head (NSWC-IHD) has determined that flowforming would be a good, cost-effective alternative to deep drawing.

The NCEMT is supporting the NSWC-IHD in the selection of specific steel alloys, development of a heat treatment process and design of manufacturing tooling to optimize the performance of the case in firing tests for both standard and Extended-Range Guided Munitions (ERGM)—all while reducing production costs.



Through testing and transitioning appropriate technology. . .

expeditiously to the broadest possible audience, the NCEMT is assisting the U.S. Army in combat vehicle research. It is the NCEMT's job to analyze, develop and engineer advanced technologies to reduce the weight of combat vehicles while balancing survivability, maintainability and life cycle cost-effectiveness.

As part of the Combat Vehicle Research Project, one of the NCEMT's specific tasks is to leverage technology developed for the space program. The NCEMT is evaluating promising technology from NASA and other sources for dissemination to the U.S. combat vehicle community. Concurrently, the NCEMT is striving to innovate new technologies that have the potential to optimize combat vehicle performance.

To meet the Army's needs, the NCEMT is working closely with the Tank Automotive Research, Development and Engineering Center (TARDEC), defense prime contractors and material suppliers. The NCEMT and its partners focus on the following six technical areas.

Surface Engineering of Aluminum Alloys

A combat vehicle is expected to operate in diverse terrain and is subject to wear, abrasion and environments that accelerate corrosion of aluminum alloys. The NCEMT is designing advanced technologies that will improve the wear and corrosion performance of wrought Al-Cu-Li 2195 and 2094 components. Engineers also are developing ways to improve abrasion resistance and sliding wear.

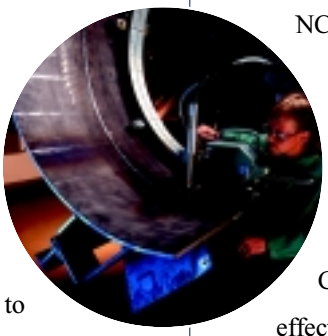
Through analysis of the electrochemical relationship between the modified surface system and the base alloy, it is possible to design a barrier layer (modified surface) that will provide additional wear and corrosion protection.

The NCEMT is examining the effectiveness of various surface chemistry modification techniques, developing processing parameters for improved surface designs and producing demonstration components.

Development of Improved Joining Procedures

The Weldalite family of Al-Li alloys was developed at Martin Marietta Laboratories to replace conventional aluminum alloys (2014 and 2219) for welded aerospace applications, specifically for cryogenic propellant (hydrogen and oxygen) tank manufacture. The Weldalite alloys become very attractive for lighter-weight, high-mobility combat vehicle applications because they are weldable, have high specific modulus and are lower in density compared to conventional aluminum armor alloy 2519.

Welding techniques developed for the NASA space shuttle external tank cover include materials from 0.320 inch to 0.650 inch in thickness. Combat vehicle applications using aluminum alloys commonly require materials that are much thicker. The NCEMT is working to leverage NASA technology to develop superior Friction Stir Welding (FSW) techniques applicable to thick-section combat vehicle materials so that maneuvers for corner welds can be simplified. Welding tools will be equipped with design features to eliminate the need for the tilt angle in thick materials. New pin designs will also be evaluated to facilitate higher travel speeds. Weldments will be made using the optimized parameters and evaluated for mechanical properties, microstructure and ballistic-shock performance.



Titanium Alloy Processing

Titanium alloys have mechanical properties equivalent to many of the ferrous alloys used in combat vehicles, but at 40 percent lower density. However, the cost of finished titanium components may be many times higher than that of ferrous components. In addition, titanium has relatively low wear resistance. The NCEMT is analyzing current combat vehicle components to determine which components can be affordably produced in new ways to take advantage of titanium's attributes. It is expected that in many cases redesigned titanium alloy components can be made at a lower cost and/or lighter weight than the same components made with other materials.

Low-cost titanium fabrication technologies are also being evaluated, and demonstration parts will be made using processes that offer the greatest potential to improve the total affordability and reliability of combat vehicles.

Fabrication of Lightweight Armor

Aluminum-lithium alloys show great promise as structural materials for combat vehicles because of their high strength, low density and high degree of stiffness. For example, when Al-Cu alloy 2219 was replaced by aluminum-lithium alloy 2195 on the external tank of the space shuttle, the weight savings of the 60,000-pound tank was approximately 8,000 pounds. The

NCEMT is evaluating selected high-strength, corrosion-resistant aluminum alloys for use as armor plate and extruded components of combat vehicles.

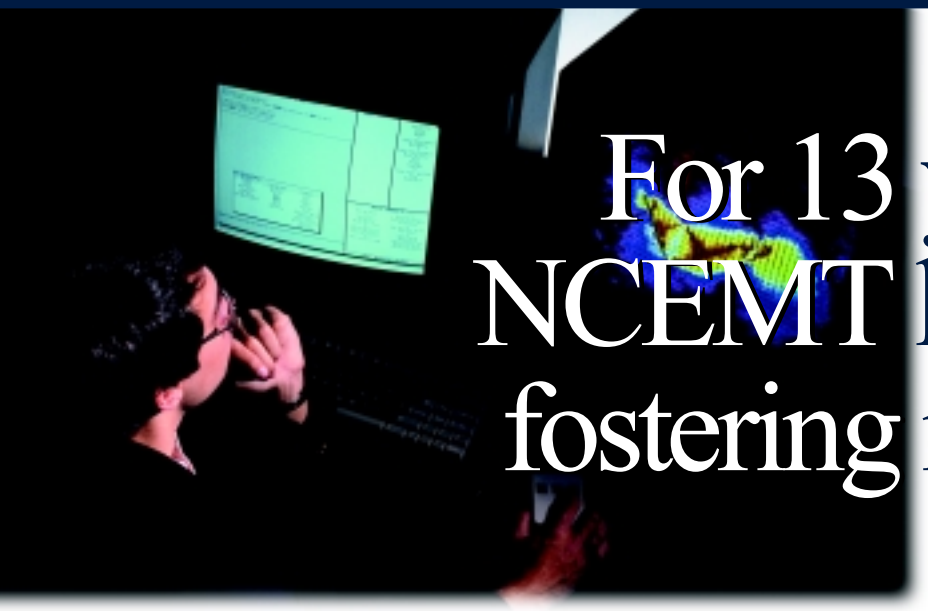
Several key subtasks are also underway. In conjunction with the University of Delaware Center for Composite Manufacturing, the NCEMT is evaluating the effects of comprehensive pre-loading on the ballistic performance of ceramic tile armor systems. The NCEMT is also working with prime contractors, TARDEC and material suppliers to identify appropriate plate thickness for ballistic testing and making Al-Li materials available for selected combat vehicle component-prototype development.

Demonstrating Advanced Fabrication Technology

The major objective of this task is to demonstrate fabrication of lightweight combat vehicle subcomponents. The NCEMT is evaluating the design, manufacturability and fabrication of space-frame technologies for combat vehicles. Space-frame design offers the potential to dramatically reduce vehicle weight while maintaining structural integrity.

Innovative Processing Technologies

Making the best even better involves rigorous testing and innovation. Collaboration—soliciting the brightest ideas from the finest sources—is also essential. To execute the Innovative Processing Technologies Task, the NCEMT is working with combat vehicle manufacturers, the U.S. Army and other technology partners. The objective is to further enhance the tools available to U.S. warfighters by maturing two or three current combat vehicle technologies and defining implementation paths for other advanced technologies. ✪



For 13 years, the NCEMT has been fostering new ideas. . .

and making exciting strides in advanced metalworking technology. But that's not enough. The NCEMT begins planning for technology transfer at the start of each new project so that successful outcomes and useful information are disseminated to applicable civil-military industrial audiences as quickly as possible.

It is the NCEMT's goal to extend the benefits of its progress through concise, expeditious technology transfer to any key Navy, government or industrial organizations that may stand to benefit.

By incorporating technology transfer early in the planning stages of each project, the NCEMT is poised to begin advancing information through a variety of means including one-on-one assistance, seminars, exhibits, project demonstrations, interactive electronic databases, articles and videos.

Here are highlights of several highly significant technology transfer activities the NCEMT participated in this year.

Shipbuilding Technologies 2001

A shipbuilding technologies information exchange held September 5– 6, 2001, in Biloxi, Mississippi, brought together industry, government and academic leaders to discuss a common goal: reducing total ownership costs of Naval ships while enhancing the competitiveness of the domestic shipbuilding industry.

The NCEMT facilitated the two-day event, which was sponsored by the Office of Naval Research, Navy Manufacturing Technology (MANTECH) Program and the National Shipbuilding Research Program—Advanced Shipbuilding Enterprise.

More than 200 attendees shared information regarding technical developments and the progress of ongoing projects aimed at providing innovative technologies, materials and tools to the shipbuilding community. Experts from the NCEMT presented recent advances in Friction Stir Welding (FSW) of both steel and aluminum for Naval applications.

Keynote addresses emphasized the need for collaboration between shipyards and research organizations to meet the challenges ahead. Delivering keynote speeches were Rear Admiral Charles Young, Vice Commander, Naval Sea Systems Command; Rear Admiral Jay Cohen, Chief of Naval Research (by video) and Rear Admiral Paul Robinson, U.S. Navy (retired) and current Vice President, Operations, for Northrop Grumman Ship Systems Ingalls Operations. Panel discussions centered on national shipbuilding issues key to shipbuilding vitality.

To conclude the exchange, Northrop Grumman Litton Ingalls Shipyard in nearby Pascagoula, Mississippi, hosted a tour of their shipyard, which included a privileged opportunity to see the USS Cole ready for re-launch. On September 14, just days after Shipbuilding Technologies 2001 concluded, the USS Cole re-launch took place—one day ahead of schedule.

International Outreach Activities

NCEMT engineers shared information on FSW with international audiences over the past year.

Kevin Colligan, Jim Fisher and Joe Pickens authored a paper, "Friction Stir Welding of Aluminum Armor Alloy 2519 for the Advanced Amphibious Assault Vehicle (AAAV)," for presentation at the 12th Annual AeroMat Conference. The conference, held in California June 2001, drew experts from around the world.

Two presentations were made at the Third International Symposium on FSW held at Kobe, Japan. Kevin Colligan presented a paper titled "Friction Stir Welding of Thick-Section Corner Welds in 5083-H131 and 2195-T8P4 Aluminum Plates." Paul Konkol presented a paper on "Friction Stir Welding of HSLA-65 Steel for Shipbuilding." Both papers were based on work the NCEMT is doing for the Combat Vehicle Research Program.

FSW was invented in 1991 by The Welding Institute (TWI) of the United Kingdom. Because it is so new, FSW is the subject of very active worldwide research. The new metalworking technique is most commonly used with aluminum, but the NCEMT is making great strides in adapting FSW for steel.

By February 2002 the NCEMT expects to have operational the largest FSW system in America—one of two machines of its size in the world. The new FSW unit has a horizontal axis of 26 feet and is 13 feet high, which will enable the NCEMT to weld full-size combat vehicles.

Another first for America. One more significant NCEMT-led solution to making U.S. combat weapons systems lighter, stronger and less expensive to produce so that more can be made. ✪

National Center for Excellence in Metalworking Technology

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Page 1 .....

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Page 2 .....

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Page 4 .....

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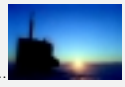
Page 4 .....



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Page 5 .....

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Page 6 .....

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Page 6 .....

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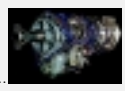
Page 7 .....



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Page 7 .....

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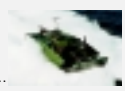
Page 8 .....



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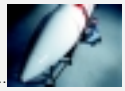
Page 9 .....



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Page 9 .....